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(71) Applicant: SAMSUNG ELECTRONICS CO., LTD.
Suwon-City, Kyungki-do (KR)

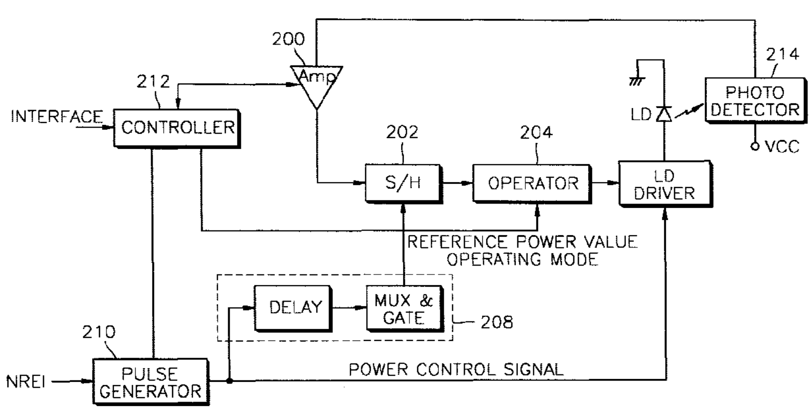
(72) Inventors:
- Seo, Jin-gyo
Suwon-city, Kyungki-do (KR)
- Jin, Kyoung-bog, I.P.T Digital Media R&D Center
Paldal-gu, Suwon-city, Kyungki-do442-370 (KR)
- Go, Sung-ro
Kunpo-cit, Kyungki-do (KR)

(74) Representative: Chugg, David John et al
Appleyard Lees,
15 Clare Road
Halifax, West Yorkshire HX1 2HY (GB)

(54) Apparatus and method for controlling auto laser diode power

(57) An optical recording/reproducing apparatus and a method therefor, and more particularly, an auto laser diode power controlling apparatus for controlling the power of a laser diode to be in an optimal state and a method therefor are provided. The auto laser diode power controlling apparatus for controlling the output of a laser diode by comparing the current power level of an optical signal output by the LD with a reference power level and controlling the output of the LD according to the comparison result comprises a photo detector (PD) (214) for monitoring the current power level of the optical signal output by the LD, a sampler/holder (202) for sampling and holding the current power level output from the PD, a sampling and holding control signal generator (208) for generating a sampling and holding control signal for controlling the sampling operation of the sampler/holder (202) on the basis of a non return to zero inverted (NRZI) signal, and an operator (204) for comparing the current power level sampled by the sampler/holder with the reference power level and controlling the output of the LD according to the difference value. It is possible to improve recording and reproducing performance since rapid change in an optical output is appropriately controlled using different loops according to the kind and state of the disc.

FIG. 2



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Description

[0001] The present invention relates to an optical recording/reproducing apparatus and a method therefor, and more particularly, to an auto laser diode power controlling apparatus for controlling power level of a laser diode to be in an optimal state and a method therefor.

[0002] Modern society is often called an information-oriented society or a multimedia society. In this society, high capacity recording media are required. Magnetic optical disc drives (MODDs) and a digital versatile disc random access memories (DVD-RAMs), which are optical recording apparatuses, are used as the recording media. Since the optical recording apparatuses use laser diodes, the performance of equipment is determined by controlling the laser diodes to be in an optimal state. Since the types of recording pulses required by the respective optical recording devices are different, effective compensation for the different types of recording pulses are required.

[0003] Figure 1 is a block diagram showing the structure of a conventional apparatus for controlling auto laser diode power level.

[0004] The apparatus shown in Figure 1 includes an interface portion 110, a decoder 120, an address controller 130, a pulse generator 140, an auto laser diode power control (ALPC) block 150, an LD driver 160, a photodetector 170, and a time delay 180.

[0005] The interface portion 110 communicates with an external processor, for example, the microprocessor of a computer, and transmits information on recording/reproducing data, control data, and a use mode to the micro processor, and receives information on recording/reproducing data, control data, and a use mode from the micro processor.

[0006] The decoder 120 includes an address decoder 121, a register 122, and a multiplexer 123 for selecting one among various registers included in the register 122.

The address controller 130 can include various registers and sub blocks for realizing functions and controls the entire apparatus.

[0007] A laser diode driver 160 is a device in which high speed switching can be performed, and can include an additional common use IC or ASIC.

[0008] A pulse generator 140 generates a signal for generating and controlling the respective recording pulses for forming a domain on a recording medium corresponding to data to be recorded.

[0009] A time delay 180 is for delaying a signal from the pulse generator 140.

[0010] The ALPC block 150 detects a difference between a reference power level provided by the decoder 120 and the current power level provided from the photodetector 170 and controls the laser diode driver 160 according to the detection result.

[0011] The operation of the apparatus shown in Figure 1 will be described. Since the interface portion 110 is different according to the structure of a system, it is assumed that the interface portion 110 is already formed.

The decoder 120 selects and maintains a target power level (read power, erase power, and peak power as a reference power level). The selected reference power level is input to the ALPC block 150, to which at least three reference power levels such as the read power, the erase power, and the peak power are input.

[0012] The respective reference power levels are analog to digital converted by a first D/A converter 151 and provided to a comparator 152.

[0013] The photodetector signal output from the photodetector 170 is provided to the comparator 152 through a buffer (not shown).

[0014] At this time, a signal that can control the operation of the comparator 152 is generated by the pulse generator 140 and provided to the comparator 152 through the time delay 170.

[0015] An up/down counter 153 performs up or down counting according to the comparison result of the comparator 152.

The output of the up/down counter 153 is selected by a second demultiplexer 154, converted into an analog to digital signal through a second D/A converter 155, and provided to an LD driver 160.

[0016] A control signal for controlling the respective power levels provided by the ALPC block 150 and the respective power levels provided by the pulse generator 140 is input to the LD driver 160.

[0017] The apparatus shown in Figure 1 uses the up/down counter 153 in performing controlling by comparing a reference power level with a fed back current power level. However, as the reproducing and recording speed of media becomes faster, controlling speed and a control range are restricted by the operation speed of the up/down counter 153.

[0018] Since the width of a recording pulse becomes shorter and more complicated as the recording speed of media increases, a means of compensating for this is necessary.

[0019] With a view to solve or reduce the above problems, it is an aim of embodiments of the present invention to provide an auto laser diode power controlling apparatus for controlling a laser diode to be in an optimal state.

[0020] It is another aim to provide an auto laser diode power controlling method for controlling a laser diode to be in an optimal state.

[0021] According to a first aspect of the present invention, there is provided an auto laser diode power controlling apparatus for controlling the output of a laser diode by comparing the current power level of an optical signal output by the LD with a reference power level and controlling the output of the LD according to the comparison result, the apparatus comprising: a photo detector (PD) for monitoring the current power level of the optical signal output by the LD; a sampler/holder for sam-

pling and holding the current power level output from the PD; a sampling and holding control signal generator for generating a sampling and holding control signal for controlling the sampling operation of the sampler/holder on the basis of a non return to zero inverted (NRZI) signal; and an operator for comparing the current power level sampled by the sampler/holder with the reference power level and controlling the output of the LD according to the difference value.

[0022] The sampling and holding control signal generator may comprise: a delay for generating a plurality of delayed power level control signals by receiving a power level control signal for forming a recording pulse and delaying the power level control signal by different delay amounts; and a multiplexer and gate for generating a sampling and holding control signal for receiving the plurality of delayed power level control signals and combining the plurality of delayed power level control signals with each other.

[0023] The multiplexer and gate may comprise: a multiplexer for selectively outputting the plurality of delayed power level control signals; and a gate for performing logic combination on the output of the multiplexer.

[0024] The operator preferably averages the sampled photodetector signals for a predetermined period, compares the average level with the reference power level, and controls the output power level of the LD according to the difference level.

[0025] The apparatus may further comprise: a comparator for comparing the photodetector signal with the reference power level; an up/down counter for counting up or down according to the comparison result of the comparator; and a multiplexer for selecting either the output of the up/down counter or the output of the sampler/holder and providing the selected output to the operator.

[0026] The multiplexer may select the output of the up/down counter when the disc driven by the disc reproducing apparatus is a type of DVD and the output of the sampler/holder when the disc driven by the disc reproducing apparatus is a type of CD.

[0027] According to a second aspect of the invention, there is provided an auto laser diode power controlling method for controlling the output of a laser diode by comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the method comprising: (a) monitoring the current power level of an optical signal output from the LD with a photodetector (PD); (b) sampling and holding the current power level output from the PD on the basis of a NRZI signal; and (c) comparing the sampled and held current power level with the reference power level and controlling the output of the LD according to the difference level.

[0028] Step (b) may comprise: (b-1) receiving a power level control signal for forming a recording pulse, delaying the power level control signal by different delay amounts and generating a plurality of delayed power level control signals; and (b-2) receiving the plurality of delayed power level control signals, combining the plurality of delayed power level control signals with each other, and generating a control signal for performing sampling and holding.

[0029] Step (c) may comprise: step of averaging the sampled photodetector signals for a predetermined period, comparing the average level with the reference power level, and controlling the output power level of the laser diode according to the difference value.

[0030] The method may further comprise: (d) comparing the photodetector signal with the reference power level; (e) counting up or down according to the comparison result; and (f) selecting either the output of step (e) or the output of step (b) and providing the selected output to step (c).

[0031] In step (f), the output of step (e) may be selected when the disc driven by the disc reproducing apparatus is a type of DVD and the output of step (b) is selected when the disc driven by the disc reproducing apparatus is a type of CD.

[0032] According to a third aspect of the invention, there is provided an auto laser diode power controlling apparatus for controlling the output of a photodetector (PD) for monitoring the current power level of an optical signal output from a laser diode (LD) and the output of a laser diode for comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the apparatus comprising: a first auto power control (APC) means for comparing the output of the PD with the predetermined reference level, counting up or down, and outputting the counting result as a target level applied to the laser diode; a second APC means for sampling the current power level output by the PD, comparing the current power level with a predetermined reference level, and outputting the target level applied to the laser diode according to the difference level; and a selecting means for selecting either the first APC means or the second APC means according to the kind of a medium.

[0033] The selecting means may select the first APC means when the medium is a type of DVD and the second APC means when the medium is a type of CD.

[0034] The first APC means may comprise a comparing means for comparing the photodetector signal with the reference power level; and a counting means for counting up or down according to the comparison result of the comparing means.

[0035] The second APC means may comprise: a sampler/holder for sampling and holding the current power level output from the PD; a sampling and holding control signal generating means for controlling the sampling operation of the sampler/holder on the basis of a NRZI signal; and an operating means for comparing the current power level sampled by the sampler/holder with the reference power level and controlling the output of the laser diode according to the difference level.

[0036] According to a fourth aspect of the invention,

there is provided an auto laser diode power controlling method for controlling the output of a photodetector (PD) for monitoring the current power level of an optical signal output from a laser diode (LD) and the output of a laser diode for comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the method comprising: (a) a first APC step for comparing the output of the photodetector with the predetermined reference level, counting up or down, and outputting the counting result as the target level applied to the laser diode; (b) a second APC step for sampling the current power level output from the PD, comparing the current power level with a predetermined reference level, and outputting the target level applied to the LD according to the difference level; and (c) selecting either the first APC step or the second APC step according to the kind of a medium.

[0037] In step (c), the first APC step is preferably selected when the medium is a type of DVD and the second APC step is selected when the medium is a type of CD.

[0038] The first APC step may comprise: (a-1) comparing the photodetector signal with the reference power level; and (a-2) counting up or down according to the comparison result.

[0039] The second APC step may comprise: (b-1) sampling and holding the current power level output from the PD on the basis of a NRZI signal; and (b-2) comparing the sampled current power level with the reference power level and controlling the output of the LD according to the difference level.

[0040] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a block diagram showing the structure of a conventional apparatus for controlling auto laser diode power;

Figure 2 is a block diagram showing the structure of an apparatus for controlling auto laser diode power according to an embodiment of the present invention;

Figure 3 is a block diagram showing a preferred embodiment of the apparatus for controlling auto laser diode power according to the present invention;

Figure 4 is a timing diagram for schematically showing the operation of the apparatus shown in Figure 3;

Figure 5 is a timing diagram for schematically showing the generation of a sampling and holding control signal by a delayed control signal; and

Figure 6 schematically shows the operation modes of the operator shown in Figure 3.

[0041] The structure and operation of an apparatus for controlling auto laser diode power according to the present invention and a method therefor will be described in detail with reference to the attached drawings.

[0042] As shown in Figure 1, since a conventional apparatus for controlling auto laser diode power uses an up/down counter in performing control by comparing reference power level with fed back current power level, controlling speed and a control range are restricted.

[0043] Also, when the recording speed of media increases, the shape of a recording pulse becomes complicated and the width of a recording pulse becomes small.

[0044] An apparatus for controlling auto laser diode power and a method therefor including a method for sampling and holding an input signal in a desired position for a desired period are provided.

[0045] Figure 2 is a block diagram showing the structure of an apparatus for controlling auto laser diode power according to a preferred embodiment of the present invention.

[0046] Figure 2 shows an amplifier 200, a sampler/holder 202, an operator 204, a laser diode driver 206, a sampling and holding control signal generator 208, a pulse generator 210, and a controller 212, and a photodetector 214.

[0047] The output of a laser diode (LD) is controlled by the laser diode driver 206 and the output level is detected by a photodetector (PD) 214. A signal from the photodetector (PD) 214 shows the current power level of an optical signal output from the LD.

[0048] The photodetector 214 signal has a form in which the recording pulse applied to the LD is temporally delayed. The length of the delay is dependent on the operation characteristics of the LD, the PD 214, and the amplifier 200 and hardly changes after an apparatus is formed.

[0049] A recording pulse is a multiple pulse consisting of a first pulse, a multi-pulse train, a last pulse, and a cooling pulse. Each of the pulses has one power level among a read power level, a peak power level, a bias1 power level, a bias2 power level, and a bias3 power level. Namely, the level of the recording pulse changes on a temporal axis and becomes one power level among the read power level, the peak power level, the bias1 (or erase) power level, the bias2 (or cooling) power level, and the bias3 (or bottom) power level.

[0050] The recording pulse is created on the basis of a non return to zero inverted (NRZI) signal. The starting/ending positions, the pulse widths, and the power levels of the respective pulses, which form the recording pulse, change according to the correlation of front and rear spaces on the basis of the current mark.

[0051] The pulse generator 210 generates an NRZI signal and a power level control signal for turning on and

off the respective power levels according to the correlation between the mark and the space. The power level control signal includes a read control signal, a peak control signal, a bias1 control signal, a bias2 control signal, and a bias3 control signal for controlling the read power level, the peak power level, the bias1 power level, the bias2 power level, and the bias3 power level, respectively.

[0052] The sampler/holder 202 samples the size of a photodetector 214 signal at a certain point in time, obtains the current power level, and provides the obtained current power value to the operator 204.

[0053] The operator 204 compares the reference power level with the sampled current power value and controls the output of the LD according to the comparison result. To be specific, the operator 204 changes the level of the driving power provided to the LD according to the comparison result. The LD driver 206 changes the output of the LD according to the driving power level change value.

[0054] The driving powers corresponding to the respective power levels are provided to the LD driver 206. The level of the driving power varies according to the output of the operator 204. Also, the LD driver 206 drives the LD by selectively combining the respective driving power levels and the driving power level is selected by a power level control signal.

[0055] Figure 3 is a block diagram showing a preferred embodiment of the apparatus for controlling auto laser diode power according to the present invention.

[0056] The apparatus shown in Figure 3 includes a reference digital to analog converter (DAC) 302, a switching amplifier 304, a comparator 306, analog-to-digital converters (ADCs) 308 through 312, up/down counters 314 through 322, multiplexers 324 through 332, operators 334 through 342, DACs 344 through 352, samplers and holders 354 through 358, a multiplexer and gate 360, a delay 362, a pulse generator 364, an NRZI detector 366, a controller 368, a serial interface 370, and a monitor 372.

[0057] The reference ADC 302 analog-to-digital converts the reference power level provided by the controller 368 and provides the analog-to-digital converted value to the inversion input terminal of the comparator 306.

[0058] The reference power level varies according to a disc format such as CD, CD-R, DVD, DVD-RW, and DVD+RW, the kind of a medium, and a manufacturing company and is provided to the controller 368 through the interface 370. The controller 368 stores the reference power level in the form of a table, reads contents stored in a table according to a disc format, the kind of a medium, a manufacturing company, and an operation mode, and provides the contents to the reference DAC 302.

[0059] The switching amplifier 304 amplifies a photodetector signal according to a predetermined gain and provides the amplified photodetector signal to the non-inverting input terminal of the comparator 306. The output of the switching amplifier 304 shows the current power level. In Figure 3, a monitor front PD signal denotes a photodetector signal that is the output of a photodetector (PD).

[0060] The switching amplifier 304 is a variable gain amplifier and the gain thereof is non-linearly controlled. The gain of the switching amplifier 304 is set according to an operation mode and whether the recording surface of a disc is land or a groove.

[0061] The comparator 306 compares the reference power level provided by the reference DAC 302 with the current power level provided by the switching amplifier 304 and outputs a value of 0 or 1 according to the comparison result. The output of the comparator 306 is provided to the up/down counters 314 through 322.

[0062] The up/down counters 314 through 322 count up or down according to the comparison result of the comparator 306. The initial set values of the up/down counters 314 through 322 are provided by the controller 368 and are slightly different from the reference power level. It is preferable that the difference between the initial set level and the reference power level is small so that the current power level traces the reference power level quickly. However, the difference between the initial set level and the reference power level is preferably determined according to the gain and the response speed of related circuits.

[0063] The multiplexers 324 through 332 select one among two feed back loops as described below.

[0064] The operators 334 through 342 operate on the mean value of the sampled current power levels, operate on the difference value between the mean value and the reference power level, control the power level, and maintain the operated value.

[0065] The DACs 344 through 352 analog to digital convert the outputs of the operators 334 through 342 and provide the analog to digital converted outputs to a LD driver (not shown).

[0066] The samplers and holders 354 through 358 sample and hold the photodetector signal output from the switching amplifier 304. The outputs of the samplers and holders 354 through 358 are analog-to-digital converted through the ADCs 308 through 312 and provided to the operators 334 through 352 through the multiplexers 324 through 332.

[0067] The multiplexer and gate 360 generates a sampling and holding control signal for controlling the sampling and holding operation of the samplers and holders 354 through 358. Though not shown, multiplexers and gates 360a, 360b, and 360c include multiplexers and logic gates.

[0068] The multiplexer of the multiplexer and gate 360 selects one or a plurality of signals among the delayed read control signal, the delayed peak control signal, the delayed bias1 control signal, the delayed bias2 control signal, and the delayed bias3 control signal, which are provided by the delay 362. The gate performs a logic combination on the output of the multiplexer and gener-

ates a sampling and holding control signal. The simplest form of the gate is an AND gate.

[0069] The delay 362 includes a plurality of delay devices and delays and outputs the read control signal, the peak control signal, the bias1 control signal, the bias2 control signal, and the bias3 control signal, which are generated by the pulse generator 364.

[0070] A section for sampling can be easily selected by the operations of the delay 362 and the multiplexer and gate 360. A desired portion of the fed back photodetector signal can be sampled using the section.

[0071] The pulse generator 364 generates the read control signal, the peak control signal, the bias1 control signal, the bias2 control signal, and the bias3 control signal. The starting/ending position and the pulse width of each signal are determined by the NRZI detector 366.

[0072] The NRZI detector 366 receives the NRZI signal and detects correlation between the current mark and front and rear spaces. The detection result is provided to the pulse generator 364 and determines the starting/ending position and the pulse width of each control signal.

[0073] The controller 368 provides the reference power level received through the interface portion 370 to the reference DAC 302 and the operators 334 through 342 and sets the initial values of the up/down counters 314 through 322. The controller 368 controls the gain of the switching amplifier 304, the switching positions of the multiplexers 324 through 332, and the operation modes of the operators 334 through 352 according to the operation mode, the kind of a medium, and a disc format and whether the recording surface of a disc is land or a groove.

[0074] The monitor 372 monitors the current power level and performs interrupt to be generated by the current power level.

[0075] In general, the samplers and holders 354 through 358 and the ADCs 308 through 312, which are shown in Figure 3, are used in the state of being integrated. However, they are shown to be separated from each other for the convenience of explanation.

[0076] The operations of the apparatus shown in Figure 3, will be described in detail.

[0077] Auto laser diode power control means controlling the power level of a laser during recording/reproducing in an optical disc. Since the output of the laser changes according to temperature, control for making the laser output uniform in spite of a change in operation temperature is necessary. The control is referred to as laser output control. The auto laser diode power control is performed in order to stabilize the laser output with respect to change in temperature and to prevent deterioration of recording caused by thermal accumulation in a multi-train recording method.

[0078] The apparatus for controlling the auto laser diode power according to the present invention consists of two loops. A first loop is used in the case where the response time of a controlling circuit does not need to be fast. The first loop consists of the switching amplifier 304, the reference DAC 302, the comparator 306, the up/down counters 314 through 322, the operators 334 through 342, the DACs 344 through 352, an LD driver (not shown), an LD (not shown), a PD (not shown), and a current/voltage converter (I/V) (not shown).

[0079] A second loop is used in the case where the response time of the controlling circuit must be fast. The second loop includes the switching amplifier 304, the samplers and holders 354 through 358, the operators 334 through 342, the DACs 344 through 352, the LD driver (not shown), the LD (not shown), the PD (not shown), and the I/V (not shown).

[0080] The multiplexers 324 through 332 select either the first loop or the second loop according to the kind of a medium.

1) Explanation of the operation of the first loop

[0081] The switching amplifier 304 amplifies the output signal of the PD. The photodetector signal output from the PD denotes the current power level and has the waveform of a delayed recording pulse.

[0082] The gain of the switching amplifier 304 varies according to the operation mode of a disc driver, that is, a reproducing mode, a recording mode, and an erasing mode. The photodetector signal amplified by the switching amplifier 304 is input to the noninverting input terminal (marked with +) of the comparator 306. Also, when the input of the switching amplifier 304 is current, the switching amplifier 304 performs I/V conversion.

[0083] The reference DAC 302 realized by an eight bit DAC receives the reference power level according to the kind of a medium and the manufacturing company from the controller 368, analog to digital converts and outputs the reference power level. The reference power level output from the reference DAC 302 is input to the inverting input terminal (marked with -) of the comparator 306.

[0084] The first through fifth up/down counters 314 through 322 count up or down by one bit according to the output of the comparator 306.

[0085] The first through fifth up/down counters 314 through 322 are used to control the read power, the peak power, the bias1, the bias2, and the bias3, respectively.

[0086] Though not shown in detail, each of the first through fifth up/down counters 314 through 322 includes two up/down counters. One is for land and the other is for a groove.

[0087] The first through fifth up/down counters 314 through 322 count down when the current power level is larger than the reference power level and count up when the current power level is smaller than the reference power level, as a result of comparison of the comparator 306.

[0088] The initial set levels of the first through fifth up/down counters 314 through 322 are provided by the controller 368. It is preferable that the difference between

the initial set level and the reference power level is small so that the current power level can trace the reference power level quickly.

[0089] The first through fifth operators 334 through 342 perform operations according to the operation modes provided by the controller 368. The first through fifth operators 334 through 342 are used for operating the read power, the peak power, the bias1 (erase) power, the bias2 (cooling) power, and the bias3 (bottom) power. The operation modes provided by the controller 368 are a sub-ALPC mode, an average ALPC mode, and a sub-average ALPC mode.

[0090] The output signals of the first through fifth DACs 344 through 352 drive the LD (not shown) through the LD driver (not shown). The output of the LD is monitored by the PD (not shown) and fed back to the switching amplifier 304 shown in Figure 3.

2) Explanation of the operation of the second loop

[0091] The NRZI detector 366 detects data to be recorded using NRZI data as an input. The NRZI detector 366 detects a predetermined correlation according to the sizes of front and rear spaces on the basis of the current mark and outputs the detection result to the pulse generator 364. According to an adaptive controlling method, the length of the current mark and the combination of the front and rear spaces are divided into several groups according to the length of the mark and the space. The power levels, the starting/ending positions, and the pulse widths of the respective pulses, which form the recording pulse, vary in each divided group. The power level of each pulse varies according to the energy of the NRZI signal. Here, the energy denotes the number of times the NRZI signal is converted from 0 to 1 and from 1 to 0 per unit time.

[0092] The pulse generator 364 generates power level control signals (c) through (f) of Figure 4 for forming a recording pulse (b) of Figure 4, which is suitable for the detection result of the NRZI detector 366, the laser diode, the kind of a medium, and the recording speed provided by the controller 368.

[0093] The delay 362 delays and outputs the power level control signals output from the pulse generator 364.

[0094] The multiplexer and gate 360 selects and combines the delayed power level control signal provided by the delay 362 and outputs a sampling and holding control signal for controlling each of the samplers and holders 354 through 358.

[0095] The samplers and holders 354 through 358 perform sampling on the PD signal while the samplers and holders 354 through 358 are activated by the sampling and holding control signals. The samplers and holders 354 through 358 and the ADCs 308 through 312 continuously perform sampling and digital converting operations in a section where the second loop is activated and the sampling and holding signal is activated.

[0096] The samplers and holders 354 through 358 sample the read power, the peak power, and the bias power.

[0097] The photodetector signal sampled by the samplers and holders 354 through 358 is digitally converted through the ADCs 308 through 312 and is provided to the operators 334 through 342.

[0098] The operators 334 through 342 compare the power level sampled by the samplers and holders 354 through 358 with the reference power level provided by the controller 368 according to the operation mode provided by the controller 368 and control the power level of the LD according to the comparison result.

[0099] The monitor 372 performs a laser diode test mode (LTM) or interrupt.

[0100] The LTM can be selectively performed and is used for examining the LD and examining or correctly calibrating the respective power levels during the initialization of the laser diode or the operation of the LD. Since the LD outputs an optical signal having power for recording during the performing of the LTM, the previously recorded material can be affected by the optical signal. Therefore, when the LTM is performed, recorded materials must be protected by moving a pick-up (not shown) to the inner-most or outer-most circumference of a disc or by moving an objective lens up or down as far as it will go using a focus servo (not shown).

[0101] In the case of a 4.7GB DVD-RAM, since the ranges of bias power levels are the same, that is, 0 through 10 mW, it is possible to realize the ALPC including only the third ADC 312.

[0102] The output signals of the first through fifth DACs 344 through 352 drive the LD. The output level of the LD is fed back to the switching amplifier 304 from the PD.

[0103] In the case of the first loop using the first through fifth up/down counters 314 through 322, tracing speed is low since the first loop traces the reference power level, while moving by only one bit at one time. However, in the case of the second loop using the first through third ADCs 308 through 312, the tracing speed is high since it is possible to change all of the bits at one time without restriction.

[0104] In the case of a DVD-RAM, the first or second loop is used since it is a mirror or gap region in which data is not recorded. In the case of a CD-RW or CD+RW, in which there is no mirror or gap region, the second loop is preferably used.

[0105] In the embodiment of the present invention shown in Figure 3, it is possible to control the output of the laser diode more precisely by adopting the control structure having two loops. It is easy to maintain an output control value to be temporally infinite or to arbitrarily change the output control value.

[0106] The feedback loop using the first through fifth up/down counters 314 through 322 can prevent rapid change in power due to an abnormal phenomenon such as noise and error. However, the response speed is re-

stricted since the feedback loop operates in units of steps. Output of the LD can be controlled by each power level in an unused user data region (the gap region of the DVD-RAM). A peak holder or a bottom holder is included in the comparator 306.

[0107] In the case of a medium which does not have the gap region, it is possible to control the focus servo to position the objective lens at maximum or minimum extension so that the laser is not focused on the disk and to correct each power level, while outputting each power level since there is no unused region. At this time, since the focus servo is controlled to position the objective lens at maximum or minimum extension so that the laser is not focused on the disk, an optical signal having a level less than read power level is focused on a disc. Accordingly, it is possible to protect data. The reason why such a method can be performed is that the PD has a structure such that a certain amount of light is input among the outputs of the LD regardless of the position or the kind of the disc.

[0108] The feedback loop using the samplers and holders 354 through 358 and the ADCs 308 through 312 must be processed by an approximate value since some noise can be included during sampling. However, the response speed and the change width are not restricted.

[0109] Since it is possible to selectively use either the first loop or the second loop, the apparatus shown in Figure 3 can effectively control laser power according to the kind of a medium and the recording speed.

[0110] As many feedback loops as the number of required power levels are included. In the example shown in Figure 2, the power levels are the peak level, the bias1 level, the bias2 level, the bias3 level, and the read level. At this time, in the case of the ADC and the DAC, each one ADC and DAC can be used when a high speed device can be used. Namely, it is possible to digitalize the respective level values using one high speed ADC. At this time, since the ADC is a high speed ADC, the respective level values are sampled from a recording pulse without using the peak holder or the bottom holder. When a high speed DAC is used, since it is possible to change the input value by one DAC at high speed, it is possible to generate the recording pulse using one DAC.

[0111] Figure 4 is a timing diagram for schematically showing the operation of the apparatus shown in Figure 3.

[0112] In Figure 4, (a) shows an input NRZI signal. (b) shows a recording signal output from the LD. The shapes of the recording pulses change according to the kind of a medium, the recording speed, the disc manufacturing company. The recording signal shown is for a 4.7GByte DVD-RAM. The shape of the recording pulse changes according to the correlation between the mark and the space. (c) shows a control signal for controlling a peak power level. (d) is a control signal for controlling an erase power level. (e) is a control signal for controlling a cooling power level. (f) is a control signal for controlling a bottom power level. It is possible to generate the recording signal of (b) by combining the respective control signals shown in (c), (d), (e), and (f).

[0113] (g) is a fed back signal and is amplified with an appropriate gain at the moment some of the optical signal output from the LD is input to the PD and current that is output from the PD is converted into a voltage. Therefore, since it is possible to sense the power level of the light output from the LD by monitoring the signal, it is possible to appropriately control the ALPC. (h) shows a delayed peak control signal. (i) shows a delayed erase control signal. (j) shows a delayed cooling control signal. (k) shows a delayed bias control signal. The respective signals (h), (i), (j), and (k) have certain time delays. The values are equal to the time delay amounts of (b) and (g).

[0114] The time delay amounts are generated, while passing through the PD and the switching amplifier 304. In the respective signals (h), (i), (j), and (k), the dotted lines show ranges, within which sampling and holding can be performed. It is possible to create sampling and holding control signals having desired positions and widths within the ranges. Therefore, the generated sampling and holding control signals can detect the output of the LD at appropriate positions.

[0115] Figure 5 is a timing diagram schematically showing the generation of the sampling and holding control signal by the delayed control signal. In Figure 5, Q1 through Q8 of (a) through (i) are examples of the delayed control signals generated by the delay 362. (J) through (1) are sampling and holding control signals generated by the multiplexer and gate 360, the sampling and holding control signals for controlling the sampling operation of the samplers and holders 354 through 358. The delay amounts of the delayed control signals can be appropriately controlled.

[0116] The delayed control signals are selected by the multiplexer and the desired sampling and holding control signal is created using the logic gate.

[0117] The gain of the switching amplifier 304 is nonlinear. Therefore, overshoot or undershoot is generated by the photodetector signal during the conversion of the gain. Such overshoot and undershoot periods are preferably avoided in sampling the photodetector signal. In order to avoid the overshoot and undershoot periods, logic combination is performed on the delayed power level control signals.

[0118] The sampling noise caused by the ADCs 308 through 312 causes change in the power level. A slight change in the sampling noise can be ignored or avoided by averaging and then, using the sampled power level in a uniform section.

Figure 6 schematically shows the operation modes of the operators 334 through 342 shown in Figure 3. In (a) of Figure 6, a mirror or gap section is generated in the case of the DVD-RAM. The other sections are unused sections or sections where the focus server is controlled to position the objective lens at maximum

or minimum extension so that the laser is not focused on the disk. In (b), the ALPC value is continuously controlled. At this time, optical power can change as a result of sampling noise or disturbance. In (c), it is possible to reduce the change in the optical power since the ALPC value is controlled only in a specific section (the mirror or gap section) of (a) and the ALPC value is maintained at the last controlled value (the sub-ALPC mode). In (d), it is possible to reduce change in the optical power since a certain average is obtained and the average value is reflected without reflecting the respective controlled values (the average ALPC mode). At this time, it is possible to obtain the same effect as is obtained by using a low-pass filter. In the case of (e), the functions of (c) and (d) are simultaneously used. It is possible to minimize the change in the optical power due to sampling noise or disturbance since the change amount due to the average is reflected only in a specific section and the last value is maintained in the remaining sections.

[0119] As mentioned above, according to embodiments of the present invention, since rapid change in the optical output is appropriately controlled using different loops according to the kind and state of a disc, it is possible to improve recording and reproducing performance.

[0120] It will be understood by those skilled in the art that various changes in form and details may be made to the embodiments of the present invention described herein without departing from the spirit and scope of the invention as defined by the appended claims.

[0121] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0122] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0123] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0124] The invention is not restricted to the details of the foregoing embodiment(s). The invention extend to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. An auto laser diode power controlling apparatus for controlling the output of a laser diode by comparing the current power level of an optical signal output by the LD with a reference power level and controlling the output of the LD according to the comparison result, the apparatus comprising:

    a photo detector (PD) (214) for monitoring the current power level of the optical signal output by the LD;

    a sampler/holder (202) for sampling and holding the current power level output from the PD (214);

    a sampling and holding control signal generator (208) for generating a sampling and holding control signal for controlling the sampling operation of the sampler/holder (202) on the basis of a non return to zero inverted (NRZI) signal; and

    an operator (204) for comparing the current power level sampled by the sampler/holder (202) with the reference power level and controlling the output of the LD according to the difference value.

2. The apparatus of claim 1, wherein the sampling and holding control signal generator (208) comprises:

    a delay (362) for generating a plurality of delayed power level control signals by receiving a power level control signal for forming a recording pulse and delaying the power level control signal by different delay amounts; and

    a multiplexer and gate (360) for generating a sampling and holding control signal for receiving the plurality of delayed power level control signals and combining the plurality of delayed power level control signals with each other.

3. The apparatus of claim 2, wherein the multiplexer and gate comprises:

    a multiplexer for selectively outputting the plurality of delayed power level control signals; and

    a gate for performing logic combination on the output of the multiplexer.

4. The apparatus of claim 1, 2 or 3, wherein the operator (204) averages the sampled photodetector signals for a predetermined period, compares the av-

erage level with the reference power level, and controls the output power level of the LD according to the difference level.

5. The apparatus of claim 1, further comprising:

a comparator (306) for comparing the photodetector signal with the reference power level;

an up/down counter (314-322) for counting up or down according to the comparison result of the comparator (306) ; and

a multiplexer (324-332) for selecting either the output of the up/down counter or the output of the sampler/holder and providing the selected output to the operator (334-342).

6. The apparatus of claim 5, wherein the multiplexer (324-332) selects the output of the up/down counter (314-332) when the disc driven by the disc reproducing apparatus is a type of DVD and the output of the sampler/holder when the disc driven by the disc reproducing apparatus is a type of CD.

7. An auto laser diode power controlling method for controlling the output of a laser diode by comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the method comprising:

(a) monitoring the current power level of an optical signal output from the LD with a photodetector (PD) (214);
(b) sampling and holding the current power level output from the PD (214) on the basis of a NRZI signal; and
(c) comparing the sampled and held current power level with the reference power level and controlling the output of the LD according to the difference level.

8. The method of claim 7, wherein step (b) comprises:

(b-1) receiving a power level control signal for forming a recording pulse, delaying the power level control signal by different delay amounts and generating a plurality of delayed power level control signals; and

(b-2) receiving the plurality of delayed power level control signals, combining the plurality of delayed power level control signals with each other, and generating a control signal for performing sampling and holding.

9. The method of claim 7 or 8, wherein step (c) comprises:

step of averaging the sampled photodetector signals for a predetermined period, comparing the average level with the reference power level, and controlling the output power level of the laser diode according to the difference value.

10. The method of claim 7, 8 or 9 further comprising:

(d) comparing the photodetector signal with the reference power level;

(e) counting up or down according to the comparison result; and

(f) selecting either the output of step (e) or the output of step (b) and providing the selected output to step (c).

11. The method of claim 10, wherein, in step (f), the output of step (e) is selected when the disc driven by the disc reproducing apparatus is a type of DVD and the output of step (b) is selected when the disc driven by the disc reproducing apparatus is a type of CD.

12. An auto laser diode power controlling apparatus for controlling the output of a photodetector (PD) for monitoring the current power level of an optical signal output from a laser diode (LD) and the output of a laser diode for comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the apparatus comprising:

a first auto power control (APC) means for comparing the output of the PD with the predetermined reference level, counting up or down, and outputting the counting result as a target level applied to the laser diode;

a second APC means for sampling the current power level output by the PD, comparing the current power level with a predetermined reference level, and outputting the target level applied to the laser diode according to the difference level; and

a selecting means for selecting either the first APC means or the second APC means according to the kind of a medium.

13. The apparatus of claim 12, wherein the selecting means selects the first APC means when the medium is a type of DVD and the second APC means when the medium is a type of CD.

14. The apparatus of claim 12, wherein the first APC means comprises:

a comparing means for comparing the photodetector signal with the reference power level; and

a counting means for counting up or down according to the comparison result of the comparing means.

15. The apparatus of claim 12, wherein the second APC means comprises:

a sampler/holder for sampling and holding the current power level output from the PD;

a sampling and holding control signal generating means for controlling the sampling operation of the sampler/holder on the basis of a NRZI signal; and

an operating means for comparing the current power level sampled by the sampler/holder with the reference power level and controlling the output of the laser diode according to the difference level.

16. An auto laser diode power controlling method for controlling the output of a photodetector (PD) for monitoring the current power level of an optical signal output from a laser diode (LD) and the output of a laser diode for comparing the current power level with a reference power level and controlling the output of the LD according to the comparison result, the method comprising:

(a) a first APC step for comparing the output of the photodetector with the predetermined reference level, counting up or down, and outputting the counting result as the target level applied to the laser diode;

(b) a second APC step for sampling the current power level output from the PD, comparing the current power level with a predetermined reference level, and outputting the target level applied to the LD according to the difference level; and

(c) selecting either the first APC step or the second APC step according to the kind of a medium.

17. The method of claim 16, wherein, in step (c), the first APC step is selected when the medium is a type of DVD and the second APC step is selected when the medium is a type of CD.

18. The method of claim 16 or 17, wherein the first APC step comprises:

(a-1) comparing the photodetector signal with the reference power level; and

(a-2) counting up or down according to the comparison result.

19. The method of claim 16, 17 or 18, wherein the second APC step comprises:

(b-1) sampling and holding the current power level output from the PD on the basis of a NRZI signal; and
(b-2) comparing the sampled current power level with the reference power level and controlling the output of the LD according to the difference level.

FIG. 1

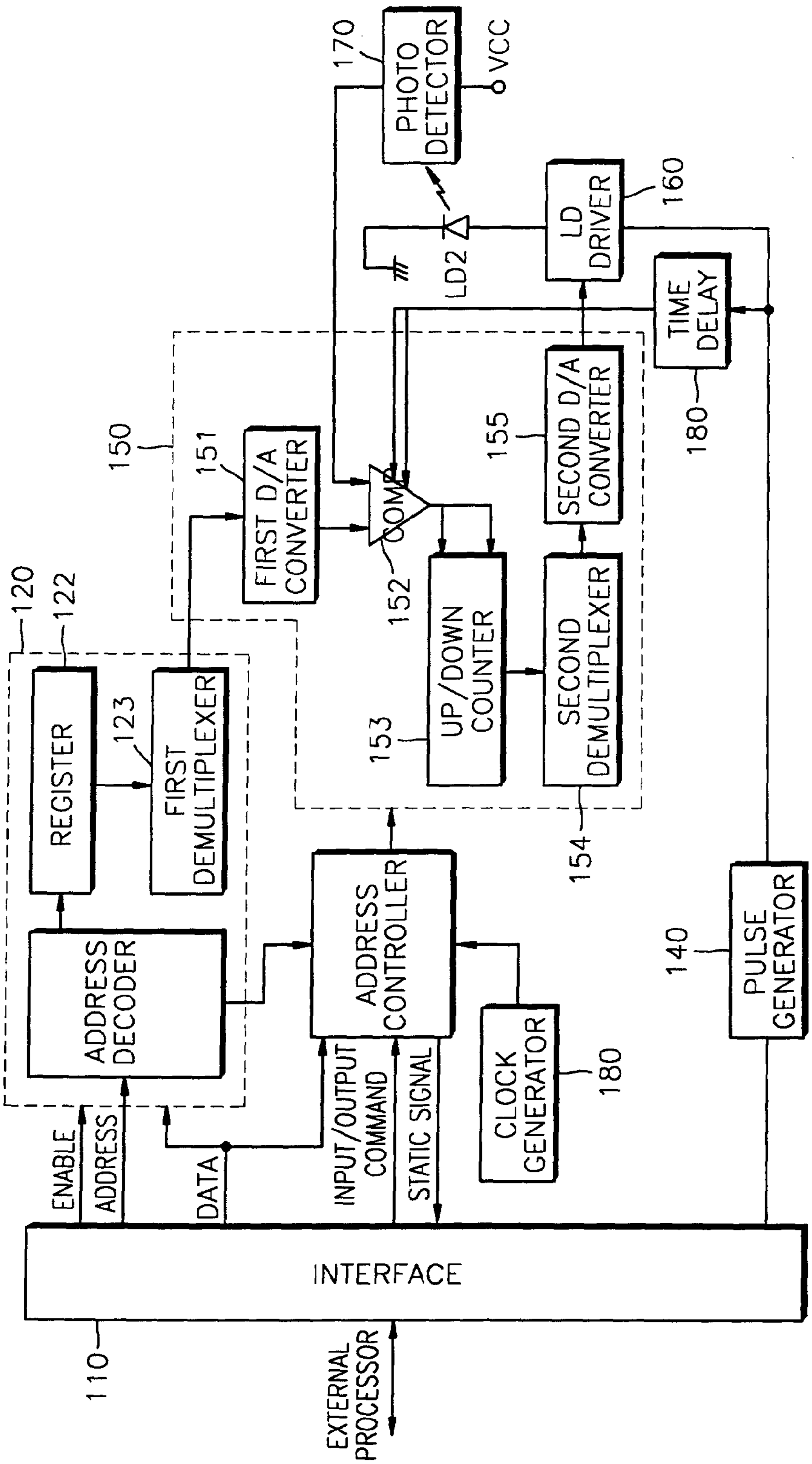

120
122
REGISTER
123
FIRST DEMULTIPLEXER
ADDRESS DECODER
150
151
FIRST D/A CONVERTER
COMP
152
UP/DOWN COUNTER
153
SECOND DEMULTIPLEXER
154
155
SECOND D/A CONVERTER
170
PHOTO DETECTOR
VCC
LD2
LD DRIVER
160
TIME DELAY
180
ADDRESS CONTROLLER
CLOCK GENERATOR
180
140
PULSE GENERATOR
ENABLE
ADDRESS
DATA
INPUT/OUTPUT COMMAND
STATIC SIGNAL
INTERFACE
110
EXTERNAL PROCESSOR

FIG. 2

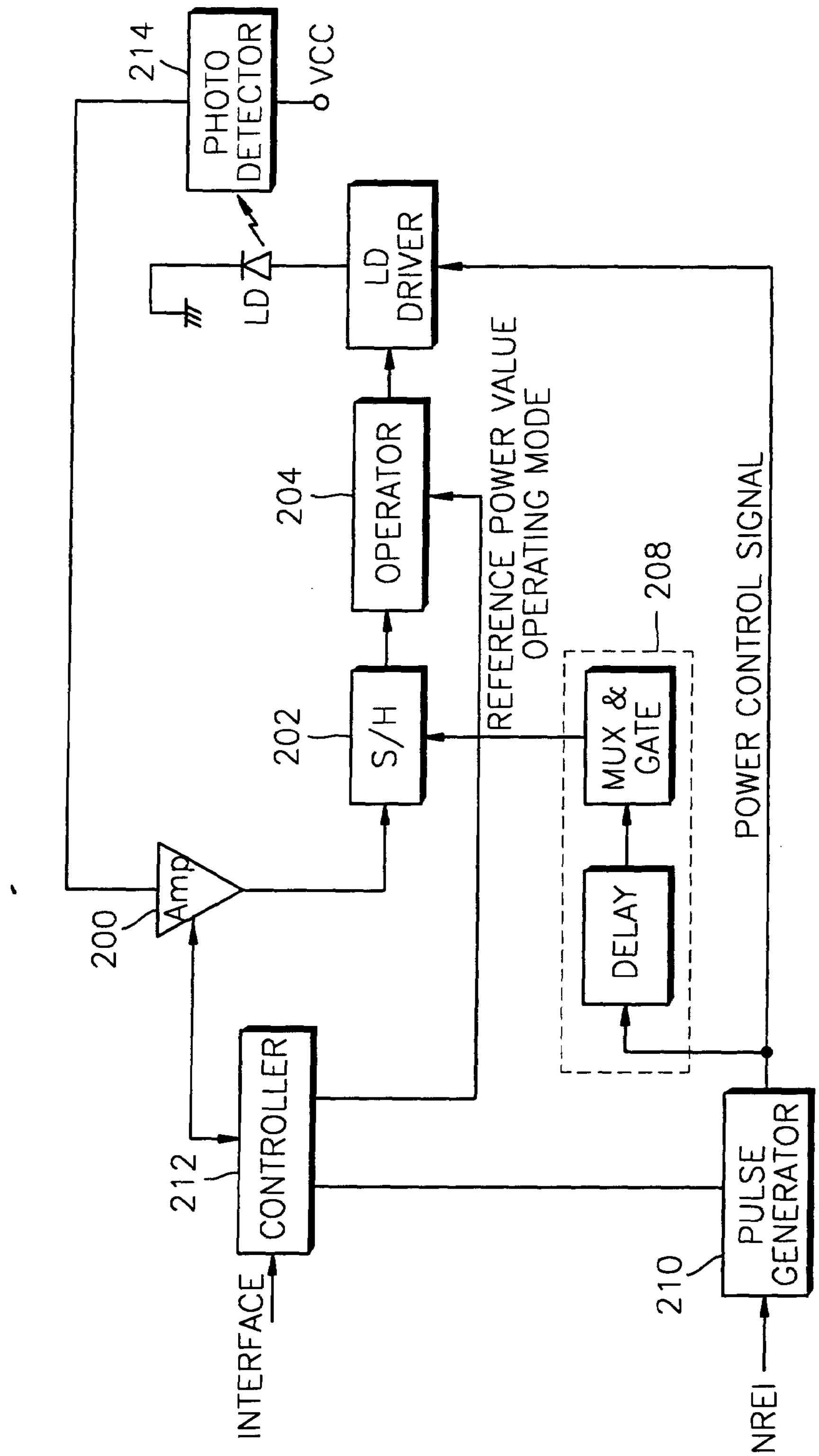


PHOTO DETECTOR
214
VCC
LD
LD DRIVER
REFERENCE POWER VALUE
OPERATING MODE
OPERATOR
204
S/H
202
MUX & GATE
DELAY
208
POWER CONTROL SIGNAL
Amp
200
CONTROLLER
212
INTERFACE
PULSE GENERATOR
210
NREI

FIG. 3

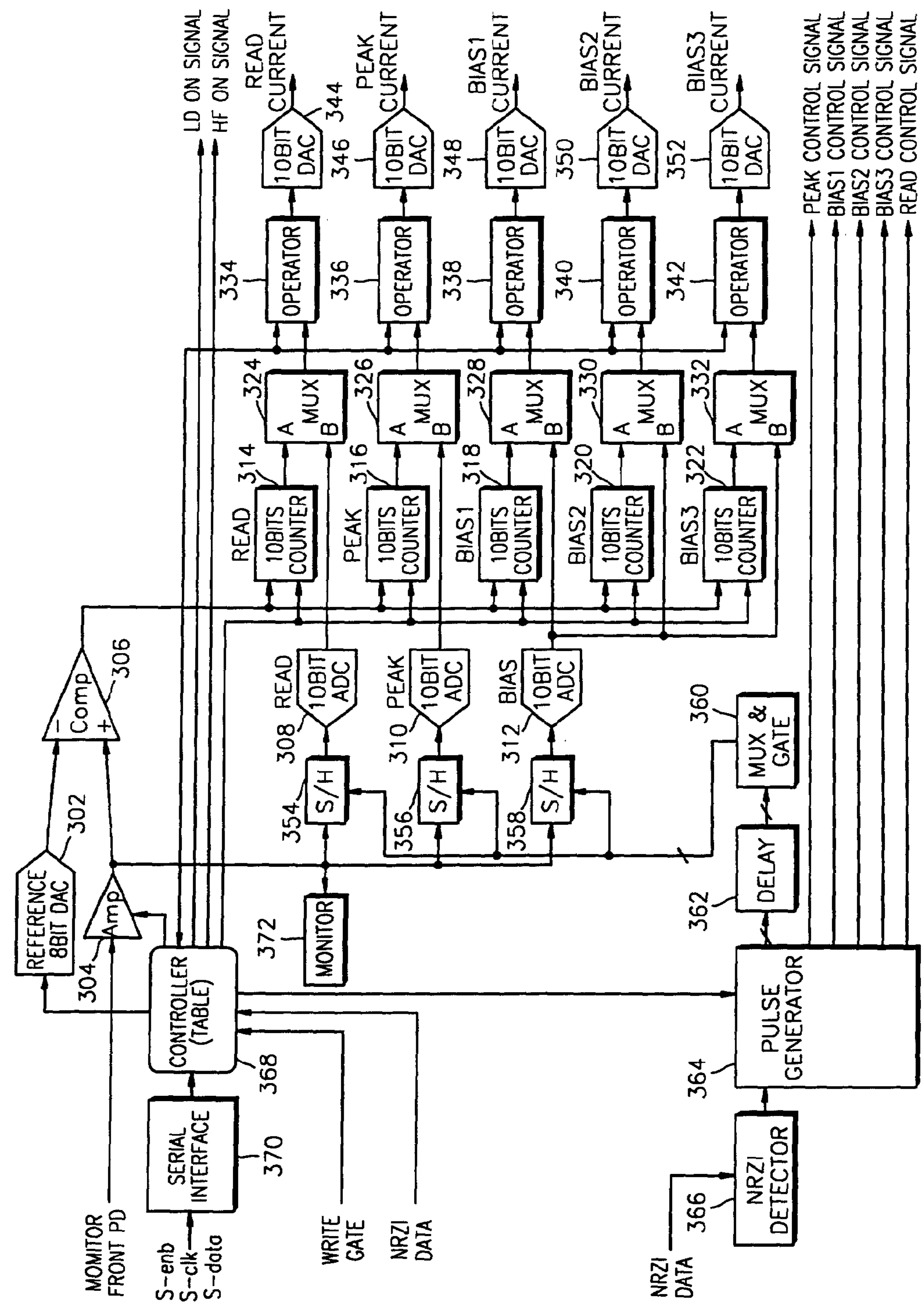

MOMITOR FRONT PD
S-enb
S-clk
S-data
SERIAL INTERFACE
370
CONTROLLER (TABLE)
368
WRITE GATE
NRZI DATA
REFERENCE 8BIT DAC
302
Amp
304
Comp
306
MONITOR
372
S/H
354
356
358
308
310
312
READ 10BIT ADC
PEAK 10BIT ADC
BIAS 10BIT ADC
READ 10BITS COUNTER
PEAK 10BITS COUNTER
BIAS1 10BITS COUNTER
BIAS2 10BITS COUNTER
BIAS3 10BITS COUNTER
314
316
318
320
322
A MUX B
324
326
328
330
332
OPERATOR
334
336
338
340
342
10BIT DAC
344
346
348
350
352
READ CURRENT
PEAK CURRENT
BIAS1 CURRENT
BIAS2 CURRENT
BIAS3 CURRENT
LD ON SIGNAL
HF ON SIGNAL
MUX & GATE
360
DELAY
362
PULSE GENERATOR
364
NRZI DETECTOR
366
NRZI DATA
PEAK CONTROL SIGNAL
BIAS1 CONTROL SIGNAL
BIAS2 CONTROL SIGNAL
BIAS3 CONTROL SIGNAL
READ CONTROL SIGNAL

FIG. 4

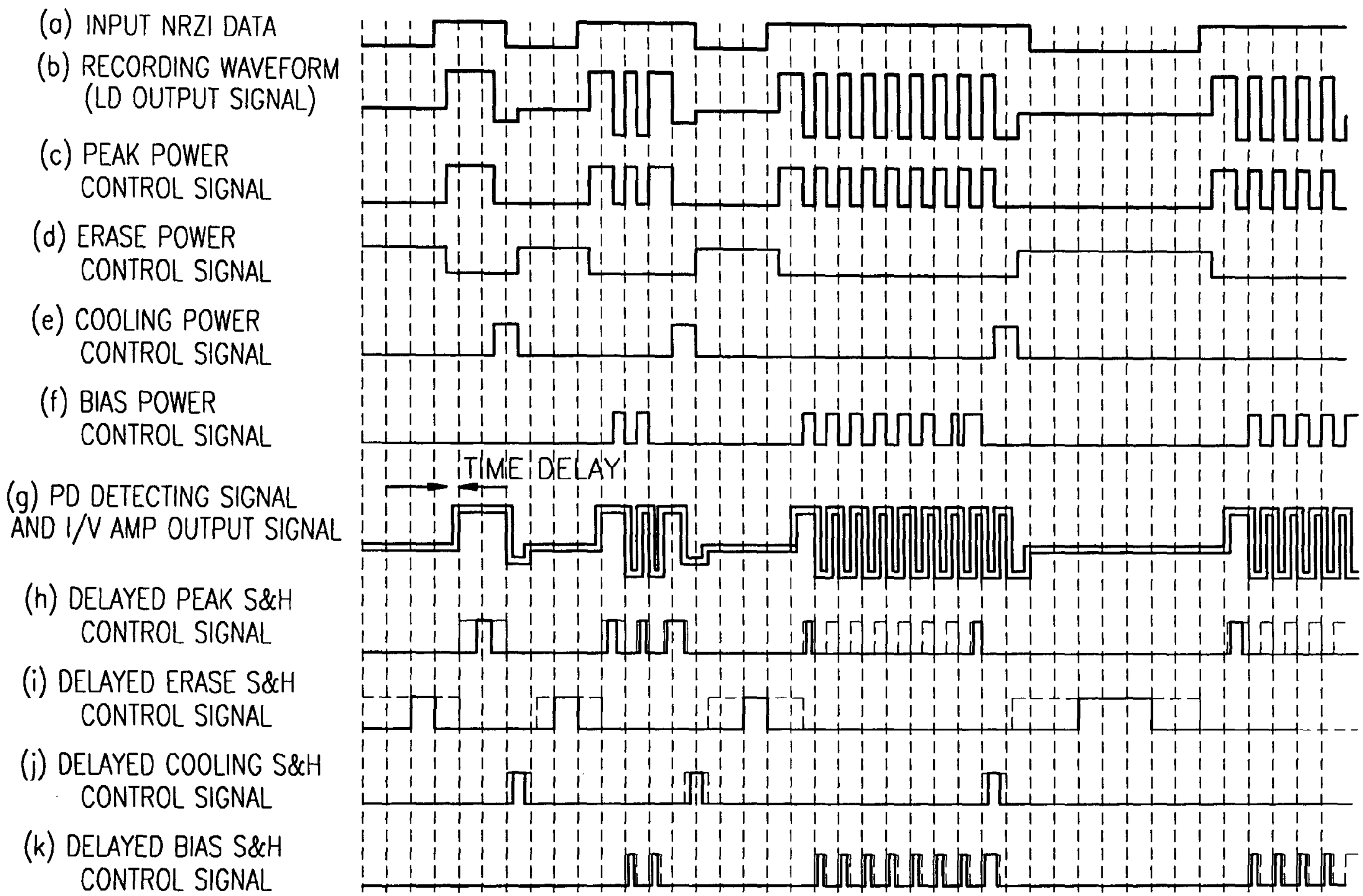

(a) INPUT NRZI DATA
(b) RECORDING WAVEFORM (LD OUTPUT SIGNAL)
(c) PEAK POWER CONTROL SIGNAL
(d) ERASE POWER CONTROL SIGNAL
(e) COOLING POWER CONTROL SIGNAL
(f) BIAS POWER CONTROL SIGNAL
TIME DELAY
(g) PD DETECTING SIGNAL AND I/V AMP OUTPUT SIGNAL
(h) DELAYED PEAK S&H CONTROL SIGNAL
(i) DELAYED ERASE S&H CONTROL SIGNAL
(j) DELAYED COOLING S&H CONTROL SIGNAL
(k) DELAYED BIAS S&H CONTROL SIGNAL

FIG. 5

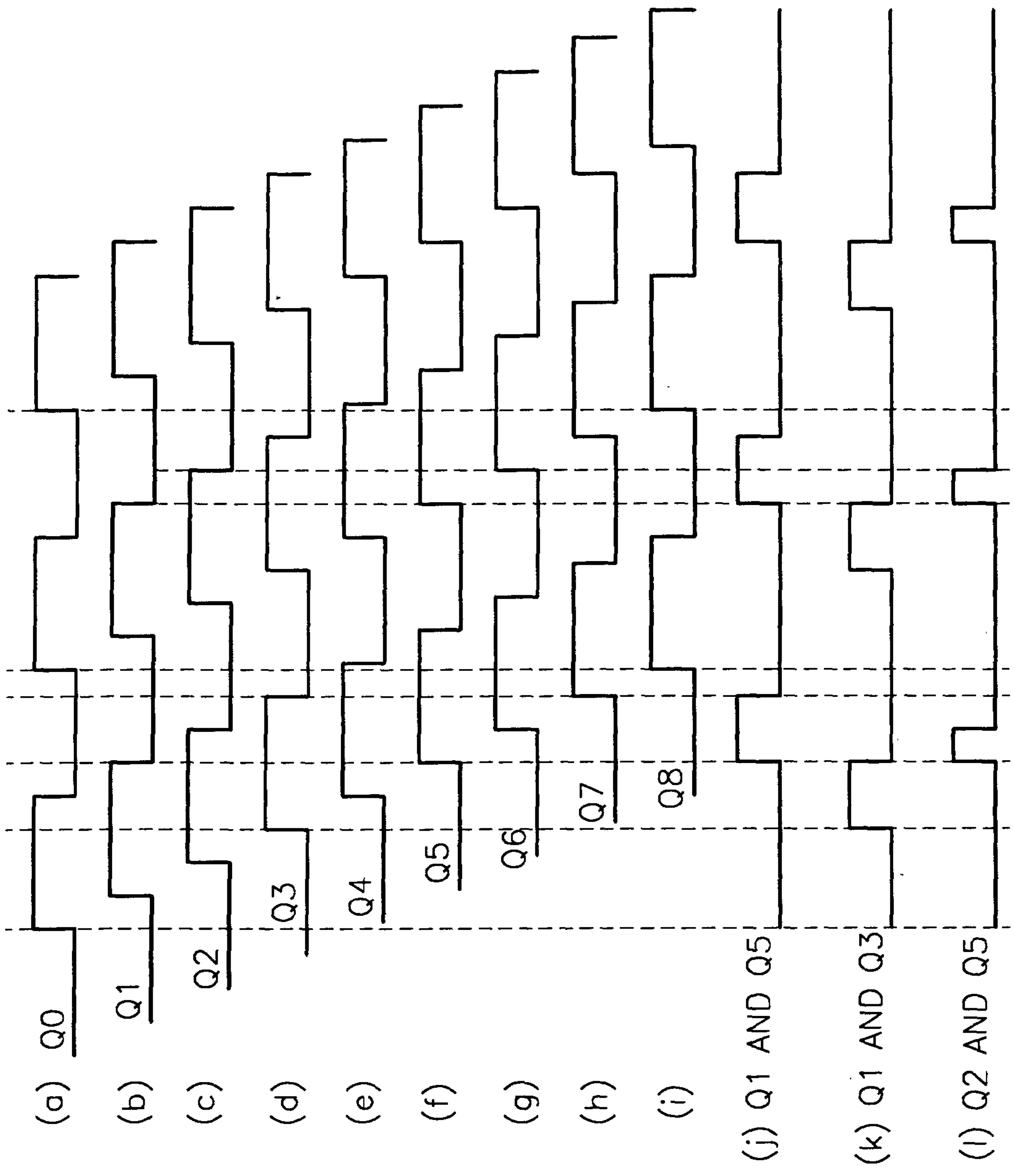
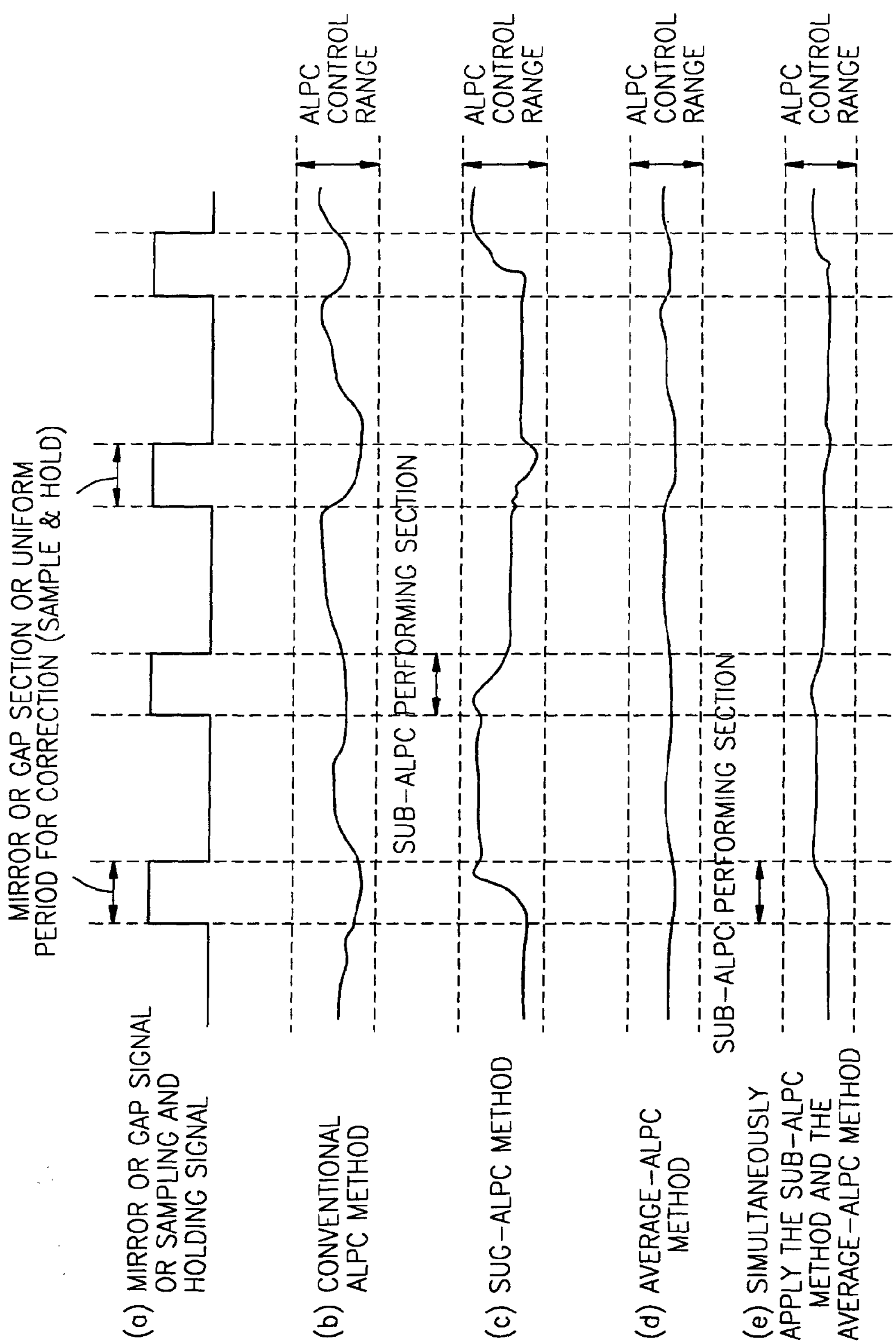

(a) Q0
(b) Q1
(c) Q2
(d) Q3
(e) Q4
(f) Q5
(g) Q6
(h) Q7
(i) Q8
(j) Q1 AND Q5
(k) Q1 AND Q3
(l) Q2 AND Q5

FIG. 6


MIRROR OR GAP SECTION OR UNIFORM
PERIOD FOR CORRECTION (SAMPLE & HOLD)
(a) MIRROR OR GAP SIGNAL
OR SAMPLING AND
HOLDING SIGNAL
(b) CONVENTIONAL
ALPC METHOD
(c) SUG-ALPC METHOD
(d) AVERAGE-ALPC
METHOD
(e) SIMULTANEOUSLY
APPLY THE SUB-ALPC
METHOD AND THE
AVERAGE-ALPC METHOD
SUB-ALPC PERFORMING SECTION
SUB-ALPC PERFORMING SECTION
ALPC
CONTROL
RANGE
ALPC
CONTROL
RANGE
ALPC
CONTROL
RANGE
ALPC
CONTROL
RANGE